Solid State Chemistry
- Artificial Lattice Alloys -

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Scope of Research

Metallic thin films, multilayers, and nanostructures are prepared by ultrahigh-vacuum deposition and electron-beam lithography. Magnetic and electric transport properties are studied using various experimental techniques including Mössbauer spectroscopy, x-ray magnetic scattering, and neutron diffraction. Novel magnetic and transport properties are explored by engineering the size and shape of magnetic materials.

Research Activities (Year 2003)

Presentations

Measurement of Propagation Velocity of a Magnetic Domain Wall in a Submicron Magnetic Wire, Himeno A, Ono T, Nasu S, Okuno T, Mibu K, Shinjo T, 18th International Colloquium on Magnetic Films and Surfaces, Madrid, 22 - 25 July.

Resistance Control by Spin Current in Manganites, Kogusu A, Ono T, Nasu S, Masuno A, Terashima T, Takano M, 18th International Colloquium on Magnetic Films and Surfaces, Madrid, 22 - 25 July.

MFM Observation of Current-Driven Domain Wall Displacement in Submicron Magnetic Wires, Yamaguchi A, Ono T, Nasu S, Miyake K, Mibu K, Shinjo T, 18th International Colloquium on Magnetic Films and Surfaces, Madrid, 22 - 25 July.

Confinement of Magnetic Domain Walls at Nanocontacts between NiFe Wires or Dots, Miyake K, Shigeto K, Ono T, Shinjo T, Mibu K, 18th International Colloquium on Magnetic Films and Surfaces, Madrid, 22 - 25 July.

Magnetic Properties of Magnetic Vortex Cores in Track Shaped Magnetic Dots, Okuno T, Shigeto K, Mibu K, Ono T, Shinjo T, 18th International Colloquium on Magnetic Films and Surfaces, Madrid, 22 - 25 July.

Spin Accumulation in Ferromagnet/Superconductor/Ferromagnet Double Tunnel Junctions, Fukuda T, Ono T, Nasu S, Okuno T, Shigeto K, Mibu K, Shinjo T, International Conference on Magnetism, Rome, 27 July - 1 August.

Weak Localization in Lacally Modulated Magnetic Field, Fuse D, Ono T, Segi T, Nasu S, Kohno H, Tatara G, Okuno T, International Conference on Magnetism, Rome, 27 July - 1 August.

Simultaneous Measurements of Magnetoresistance and Magnetic Domain Structures of L-Shaped Magnetic Wires, Yamaguchi A, Ono T, Nasu S, Miyake K, Mibu K, Shinjo T, International Conference on Magnetism, Rome, 27 July - 1 August.

Growth-Orientation Dependence of Magnetic Properties of Cr-Based Multilayers with Sn Nonatomic Layers, Jiko N, Almokhtar M, Takeda M, Suzuki J, Shinjo T, Mibu K, International Conference on Magnetism, Rome, 27 July - 1 August.

Magnetic Domain Walls and Shape-Induced Exchange Biasing Effect in NiFe Nanocontact-Structures, Miyake K, Mibu K, Ono T, Shinjo T, International Workshop on Microspectroscopy of Quantum, Magnetic and Biological Nanostructures, Osaka, 22 - 23 October.

Real-Space Observation of Current-Driven Domain Wall Displacement in Submicron Magnetic Wires, Ono T, Yamaguchi A, Nasu S, Miyake K, Mibu K, Shinjo T, International Workshop on Nano-Scale Magnetoelectronics, Nagoya, 25 - 27 November.

Grants

Ono T, Dynamics of a Single Domain Wall in Artificially Structured Magnetic Wires, Grant-in-Aid for Scientific Research (C) (2), 1 April 2003 - 31 March 2005.

Ono T, Nanospintronics Design and Realizzation, MEXT Special Coodination Funds for Promoting Science and Technology, 1 September 2002 - 31 August 2005.

Current-Driven Domain Wall Motion due to Spin-Transfer in Magnetic Nanowires

In conventional magnetic devices, the magnetic configuration has been controled by a magnetic field. Here we show that spin-polarized currents can change the magnetic state through the direct interaction between electrons and magnetic moments.

In general, ferromagnets are composed of magnetic domains, within each of which magnetic moments align. The directions of magnetization of neighboring domains are not parallel. As a result, there is a magnetic domain wall (DW) between neighboring domains. The direction of moments gradually changes in a DW as shematically illustrated in Fig. 1(a). What will happen if an electric current flows through the DW? The spin direction of a conduction electron follows the local magnetic moment when the electron crosses the DW. Thus, there is a change in angular momentum of the electron (Fig. 1(b)). To conserve the total angular momentum of the system, the angular momentum sholud be absorbed by the magnetic moments in the DW. This spin-transfer creates the torque on the DW. In consequence, the electric current moves the DW.

Magnetic wires of 10 nm-thick $Ni_{81}Fe_{19}$ were fabricated onto thermally oxidized Si substrates by means of an e-beam lithography and a lift-off method. The width of the wire is 240 nm.

Figure 2(a) shows the magnetic force microscopy (MFM) image after an introduction of a DW into the wire. The DW is imaged as a bright contrast, which corresponds to the stray field from positive magnetic charge. In this case, a head-to-head DW is realized as schematically illustrated in Fig. 1(a). After the observation of Fig. 2(a), a pulsed-current was applied through the wire in the absence of a magnetic field. The current density and the pulse duration were 1.2×10^{12} A/m^2 and 5 μs, respectively. Figure 2(b) shows the MFM image after an application of the pulsed-current from left to right. The DW moved from right to left by the application of the pulsed-current. The direction of the DW motion was reversed by switching the current polarity as shown in Fig. 2(c). The tail-to-tail DW also moved opposite to the current direction, which confirmed that the DW motion was not caused by a magnetic field generated by the current.

We can control the DW position in the wire by tuning the intensity, the duration and the polarity of the pulsed-current. Thus, spintronic devices, whose operation is based on the DW motion, can be directly operated by the current.

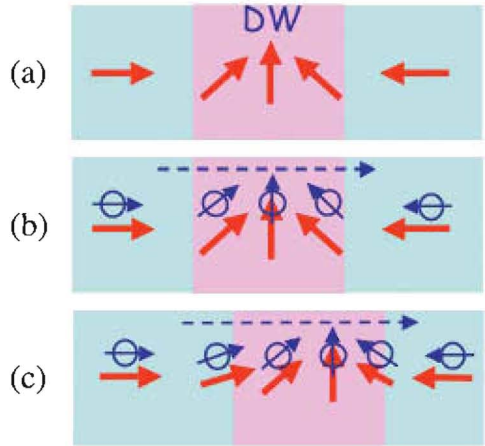

Fig. 1 Illustration of the current-driven domain wall motion due to spin-transfer effect.

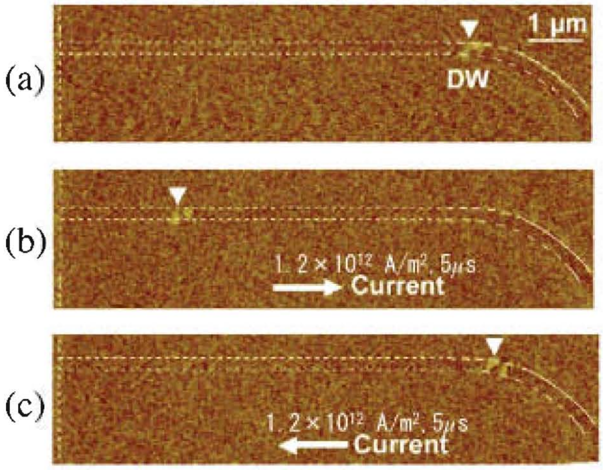

Fig. 2 Real-space observation of the current-driven domain wall motion by magnetic force microscopy.

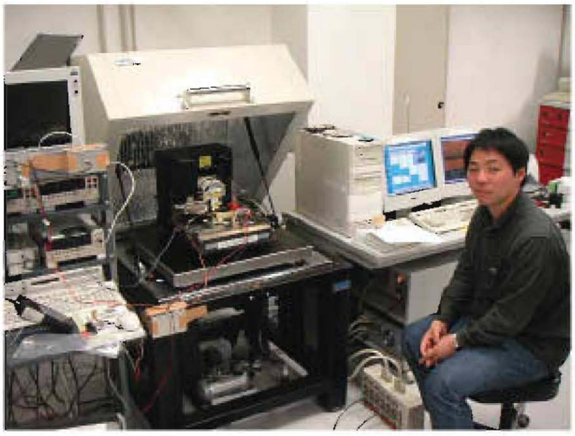

Fig . 3 Yamaguchi, A. working on MFM system.